Untangling Longitude and Latitude

Because of the Earth's shape, the same distance may correspond to different changes in longitude and latitude in different locations. To make any sense out of geographic coordinates, it is important to know how many meters or feet represent one degree (minute, second) of longitude and latitude for a given set of data points.

Explorer's Guide

Before You Start

Take a look at a globe. Describe the shape of the Earth and what do you know about lines of latitude (parallels) and longitude (meridians). Is the distance between parallels and meridians the same everywhere? Why not? If the globe was a basketball and someone would stand on the North Pole, would meridians have the same length as the Equator (as in a perfect sphere)? Why?

Learning by Doing

1. From the table below, determine the length of 1° of longitude (F_{lon}) and latitude (F_{lat}) for the following four locations:

Point No.	Longitude, °	Latitude, °	F_{lon}	F_{lat}
1	86.67	40.00	___________ m/°	___________ m/°
2	15.36	62.00	___________ ft/°	___________ ft/°
3	36.24	25.39	___________ km/°	___________ km/°
4	128.45	44.75	___________ mile/°	___________ mile/°
5				

Remember that 1 ft = 0.3048 m, 1 km = 1000 m, and 1 mile = 5280 ft. Obtain geographic coordinates for the fifth point outside using a GPS receiver. Use the linear interpolation to find values of F_{lon} and F_{lat} for the locations with fractional latitude (between lines in the table).

2. Assume that F_{lon} = 84,107 m/° and F_{lat} = 111,060 m/°. Calculate the length of:

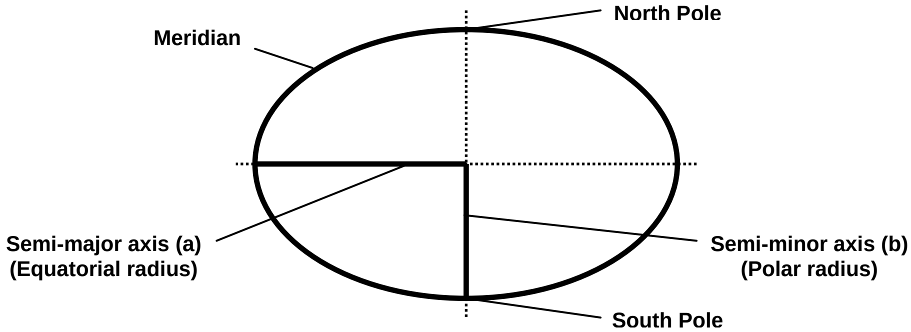
	Longitude	Latitude
0.000001° (degrees)	= _________ m = _________ ft	= _________ m = _________ ft
0.00001° (degrees)	= _________ m = _________ ft	= _________ m = _________ ft
0.001' (minutes)	= _________ m = _________ ft	= _________ m = _________ ft
0.1" (seconds)	= _________ m = _________ ft	= _________ m = _________ ft

Table. F_{lon} and F_{lat} values for the WGS-84 ellipsoid (geodetic model of the Earth used by GPS) and zero elevation.

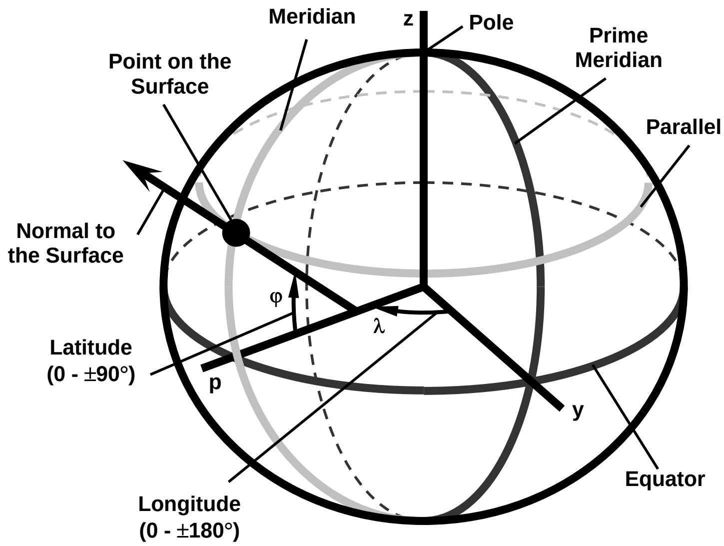
Latitude, º	F_{lon}, m/º	F_{lat}, m/º	Latitude, º	F_{lon}, m/º	F_{lat}, m/º	Latitude, º	F_{lon}, m/º	F_{lat}, m/º
0	111319	110574	30	96486	110852	60	55800	111412
1	111303	110575	31	95504	110869	61	54107	111429
2	111252	110576	32	94493	110887	62	52398	111446
3	111168	110577	33	93453	110904	63	50673	111462
4	111050	110580	34	92385	110922	64	48932	111477
5	110899	110583	35	91288	110941	65	47176	111493
6	110714	110586	36	90164	110959	66	45405	111507
7	110495	110591	37	89012	110978	67	43620	111522
8	110243	110596	38	87832	110996	68	41822	111536
9	109958	110601	39	86626	111015	69	40010	111549
10	109639	110608	40	85394	111035	70	38187	111562
11	109288	110615	41	84135	111054	71	36351	111574
12	108903	110622	42	82851	111073	72	34504	111586
13	108485	110630	43	81541	111093	73	32647	111598
14	108034	110639	44	80206	111112	74	30779	111608
15	107550	110649	45	78847	111132	75	28902	111618
16	107034	110659	46	77463	111151	76	27016	111628
17	106486	110669	47	76056	111171	77	25121	111637
18	105905	110680	48	74625	111190	78	23219	111645
19	105292	110692	49	73172	111210	79	21310	111653
20	104647	110704	50	71696	111229	80	19393	111660
21	103970	110717	51	70198	111248	81	17471	111666
22	103262	110730	52	68678	111267	82	15544	111672
23	102523	110744	53	67137	111286	83	13611	111677
24	101752	110758	54	65576	111305	84	11675	111682
25	100950	110773	55	63994	111324	85	9735	111685
26	100118	110788	56	62393	111342	86	7791	111688
27	99255	110804	57	60772	111360	87	5846	111691
28	98362	110819	58	59133	111378	88	3898	111693
29	97439	110836	59	57475	111395	89	1949	111694

How Does It Work

There are many different mathematical models representing our planet. Most of them are based on ellipsoids that assume that the North and South poles are the closest equidistant surface points with respect to the center of the Earth. Therefore, the farthest from the center of the earth points form the equator (see figure below). The distance between the center of the Earth and any point on the equator is called “semi-major axis” (a), or Equatorial radius. The distance between the center of the Earth and any of two poles is called “semi-minor axis” (b), or Polar radius. GPS technology uses the WGS-84 (World Geodetic System 1984) ellipsoid, which assumes that the semi-major axis ***a = 6,378,137 m***, and due to the specified flattening the semi-minor axis ***b = 6,356,752.3142 m***.



Geographical longitude and latitude are angular measurements. The longitude indicates an angle between the plane of the Prime meridian and the meridian passing through a point of interest. The latitude is the angle between the normal to the ellipsoid passing through the point of interest and the Equatorial plane (see figure below).



In addition to longitude and latitude, every point on the Earth surface has a third coordinate - height above ellipsoid (h). Complex terrain causes it to be different for various land locations. It is also necessary to keep in mind that the height above ellipsoid is not the same as the altitude above sea level (mean sea level), commonly used in aviation and other industries. Mean sea level elevation takes into account characteristics of a particular part of the word and is described using local models, called geoids.

Unfortunately, interpretation of geographical coordinates in terms of distance is not easy. Since all meridians intersect at two points (poles), the distance corresponding to a particular change of longitude depends on the latitude. In addition, the fact that the Earth is represented by an ellipsoid (not a spheroid) model suggests that a fixed change in latitude also corresponds to different distances depending on the north-south position. Finally, the height of an area of study over the ellipsoid affects both longitude and latitude conversion factors.

Usually, an agricultural field or other study area has a relatively small size (with respect to the size of the Earth), and may be considered as a flat surface at a particular location on the Earth. Therefore, in order to convert geographic coordinates into linear units it is necessary to define the distance corresponding to a 1º change in longitude (F_{lon}) and latitude (F_{lat}) for a specific field location (average geographic latitude and height above ellipsoid). These conversion factors could be computed using a set of derived equations given in helpers guide or obtained from the table provided above. If distances between points of interest are greater than a few miles, even more complex equations need to be used. Therefore, making calculations without appropriate software is complicated.

Additional Challenge

In which countries F_{lon} and F_{lat} are similar to those in Nebraska? How much longer, or shorter 1 mile long field (oriented East-West) near your hometown would appear if you used a value of F_{lon} obtained for a location 100 miles South of your hometown?

Vocabulary

Ellipsoid: *Mathematical body formed through rotation of an ellipse around one of its axes.*
Longitude: *an angle from -180˚ to +180˚ between plains formed by the Prime meridian and meridian passing through a given point.*
Latitude: *an angle from -90˚ to +90˚ between the plane formed by Equator and normal (perpendicular) to the spheroid in a given point.*

Interesting to Know

At a higher elevation, the length of 1˚ of longitude and latitude increases, as the surface of the ellipsoid containing a point high above ground is getting bigger.

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